STONE

A Study of the adiabatics of saturated steam

Mechanical Engineering

B. S.

1910

A STUDY OF THE ADIABATICS OF SATURATED STEAM

BY

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THESIS FOR THE DEGREE OF BACHELOR OF SCIENCE

IN MECHANICAL ENGINEERING

IN THE

COLLEGE OF ENGINEERING

OF THE

UNIVERSITY OF ILLINOIS

JUNE, 1910

UNIVERSITY OF ILLINOIS

May 31 1910

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Edison Harris Stone

ENTITLED A Study of the Adiabatics of Saturated Steam

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Mechanical Engineering

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Table of Contents.

An Investigation of the Laws of Adiabatic Expansion.

1. Introductory Statement.

An important problem in the thermodynamics of saturated vapor is the determination of the external work and the change of volume when a mixture of liquid and vapor expands adiabatically. It is possible, with the aid of any standard steam tables, to get an exact solution of these problems; yet the exact method is somewhat long and tedious. If, therefore, it were possible to represent the adiabatic projected upon the pressure-volume plane by an equation of the form $PV^n = C$; the solution would then follow that of the perfect gases, and would become a much more simple task.

It is impossible, however, to exactly represent adiabatic curves by such an

equation; yet it was shown by Zeuner that a value of n could be found which gives quite close results when compared with the older steam tables; results which for practical purposes are quite generally used.

II The work of Rankine, Grashof and Zeuner.

Rankine found the law $PV^m = C$ where m was given a value 1.1; but Rankine made no statement whether this value was to hold for all qualities or for a particular quality. From Rankine's own calculations it seems that his value was for particular conditions rather than for general use.

Following Rankine's work Grashof showed that for saturated steam in the initial condition Rankine's value was low and should be 1.14.

From the formula $PV^m = C$

we have $$\frac{P}{P_1'} = \left(\frac{V_1}{V}\right)^m$$

$$\text{or } m = \frac{\log p - \log p_1}{\log V_1 - \log V}$$

Zeuner after working out these values of m decided that the value for m was principally dependent upon the initial condition of the steam. From his tabulation of results it was found:

1. That m is greater the greater the initial quality.

2. That m depends upon the initial and final pressures. The higher the pressures the greater the value of m. Zeuner, from his results decided upon mean values of m for the different qualities and worked them into an emperical formula;

$$m = 1.035 + 0.1X,$$

which closely approximates his results.

III. Revision of Steam Tables.

Until two or three years ago all the steam tables published had been based upon the classic experiments of

Regnault. During the last few years, however, there has been a number of investigators, whose works have been quite accurate and in many ways have disagreed with the work of Regnault. The most important of these investigations are:

1. Those of Holborn and Henning who determined the pressures corresponding to given temperatures of steam. The results of this work compare quite well with the values given by Regnault the differences being slight.

2. The Throttling Experiments.

Davis from the throttling experiments of Grindley, Griessmann and Peake has deduced a new formula for total heat, which gives values higher than those given by Regnault.

3. Barnes and Dieterici have investigated the heat of the liquid; and while their results do not entirely agree they show that Regnault's formula for heat of the liquid is not correct. Marks and Davis in their work decided to give twice as much credit

to Barnes' as to Dieterici's work and plotted a new curve between the two based upon this assumption.

4. The latest work is that of Henning on the heat of vaporization. This shows that the values of the older steam tables were at fault in this respect also. These values were worked out by Henning covering a range of 180°F., from 0°F to 180°F.

5. Knoblauch, Linde and Klebe with their accurate values of v give the other important corrections in Regnault's values.

All of these determinations have led to recent revision of steam tables, of which the tables given by Marks and Davis are probably the best.

IV. Object.

The object of the present thesis, therefore, is to retrace the ground covered by Zeuner and determine whether, according to the new and more accurate values of the

properties of saturated steam the values of the exponent n in the equation $PV^n = C$. follows any law and, if necessary, to decide upon a new equation involving possibly both pressure and quality as variables.

V. Method.

The method followed in this investigation is straight forward. Dry saturated steam, or steam of a given quality x was assumed to expand adiabatically. For various lower pressures the volumes and qualities were calculated. These results are tabulated as shown by tables 1 to 10. After these calculations were completed, the simultaneous values of pressure and volume were plotted on logarithmic cross-section paper plates 1 to 4. The points were found to lie very nearly in straight straight lines, thus showing that an exponential equation was applicable. By measuring the slopes of these lines for different initial

qualities and pressures, values of n for the different conditions were obtained. A separate equation for the values of n for each initial pressure was determined by plotting on co-ordinate paper, the pressures and corresponding values of n, plates 5 to 8 and, the calculations for these curves may be found on page 10. These values of n lying on very nearly straight lines the formula for each of these pressures was in the form of a straight line

$$n = a + bx.$$

The next step was to combine these into a general equation approximating those of the individual pressures. To do this the values of a and of b obtained in these separate equations were plotted as shown by plate 9, and through the points lines representing mean values of a and of b were drawn. Substituting the equations for a and b, as determined on page 11, in the exponential equation the formula;

$$n = 1.05965 - .000313P + (.07 + .00038P)x$$

was determined, however, after using this equation it was slightly modified to give results which better satisfy the conditions.

The modified formula is:

$$n = 1.06 - .000315P + (.0706 + .000376P)x.$$

This equation shows that the value of the exponent does vary with both the pressure and the quality. It's accuracy in actual use was determined by working a few problems, first getting the second volume when the initial pressure and volume and the second pressure were known, then the work using this value for the volume just described. These problems were kept in tabular form plate 11. To check the results we have the volume given in tables 1 to 10 and the work was checked by determining the difference of energy in the two cases and by multiplying by 775.5 reduced this to the equivolent in foot-pounds.

The author feels that the success of this thesis is, in a very large sense, due to the interest taken in it by Professor Goodenough, and wishes to acknowledge the aid given by him.

Determination of Values a and b.

50 lbs.

$x = 1 \quad m = 1.133 = a + bx$

$x = .6 \quad m = 1.0973 = a + bx$

$.4B = .0357$

$B = .089$

$a = m - bx = 1.133 - .089 = 1.044$

100 lbs.

$x = 1. \quad m = 1.1376$

$x = .6 \quad m = 1.094$

$.4B = .0436$

$B = .109$

$a = m - bx = 1.1376 - .109 = 1.0286$

150 lbs.

$x = 1 \quad m = 1.1398$

$x = .6 \quad m = 1.089$

$.4B = .0508$

$B = .127$

$a = m - bx = 1.1398 - .127 = 1.0128$

200 lbs.

$x = 1. \quad m = 1.143$

$x = .6 \quad m = 1.0845$

$.4B = .0585$

$B = .146$

$a = m - bx = 1.143 - .146 = .997$

Pressure	b	a
50	.089	1.044
100	.109	1.0286
150	.127	1.0128
200	.146	.997

Determination of Equation for N.

$a = c + dP$

$P = 200 \quad a = .997$

$P = 50 \quad a = 1.044$

$150d = -.047$

$d = -.000313$

$c = 1.044 + .01565 = 1.05965$

$b = e + fP$

$P = 200 \quad b = .146$

$P = 50 \quad b = .089$

$150f = .057$

$f = .00038$

$e = .146 - .076 = .07$

Substitute in Equation $N = a + bx$

$$N = 1.05965 - .000313P + (.07 + .00038P)x$$

Modified Formula:

$$N = 1.06 - .000315P + (.0706 + .000376P)x$$

	Values of n				
P	x = 1.	x = 0.9	x = 0.8	x = 0.7	x = 0.6
50	1.1336	1.1247	1.1157	1.1068	1.09784
100	1.1367	1.1259	1.1151	1.1042	1.09342
150	1.1398	1.1271	1.1144	1.1017	1.089
200	1.1428	1.1282	1.1136	1.0991	1.08448

Table. I.

Pressure 50# — Quality 1.

$\varphi = 1.6581$

P	φ	θ	$\frac{xR_1}{T_1}$	$\frac{R_1}{T_1}$	x	U	xU	σ	V
50	1.6581	.4113	1.2468	1.2468	1.	8.4928	8.4928	.0172	8.51
25		.3532	1.3049	1.3604	.9592	16.2831	15.619	.0169	15.6359
10		.2832	1.3749	1.5042	.9142	38.3634	35.069	.0166	35.0856
5		.2348	1.4233	1.6082	.8849	73.3135	64.796	.0165	64.8125
2		.1749	1.4832	1.7431	.8508	173.4836	147.6	.0164	147.6164

Pressure 50# — Quality 0.9

$\varphi = .4113 + (.9 \times 1.2468) = 1.5323$

P	φ	θ	$\frac{xR_1}{T_1}$	$\frac{R_1}{T_1}$	x	U	xU	σ	V
50	1.5323	.4113	1.121	1.2468	.9	8.4928	7.6435	.0172	7.6607
25		.3532	1.1791	1.3604	.8667	16.2831	14.113	.0169	14.1299
10		.2832	1.2491	1.5042	.8304	38.3634	31.958	.0166	31.9646
5		.2348	1.2975	1.6082	.8066	73.3135	59.056	.0165	59.0725
2		.1749	1.3574	1.7431	.7787	173.4836	135.1	.0164	135.1164

Table. 2.

Pressure 50# — **Quality 0.8**

$\varphi = .4113 + (.8 \times 1.2468) = 1.4073$

P	φ	Θ	$\frac{xR_1}{T_1}$	$\frac{R_1}{T_1}$	x	u	xu	σ	V
50	1.4073	.4113	.996	1.2468	.8	8.4928	6.7924	.0172	6.8114
25		.3532	1.0541	1.3604	.77485	16.2831	12.618	.0169	12.6349
10		.2832	1.1241	1.5042	.74734	38.3634	28.66	.0166	28.6766
5		.2348	1.1725	1.6084	.729	73.3135	53.37	.0165	53.3865
2		.1749	1.2324	1.7431	.6909	173.4836	119.86	.0164	119.8764

Pressure 50# — **Quality 0.7**

$\varphi = .4113 + (.7 \times 1.2468) = 1.2833$

P	φ	Θ	$\frac{xR_1}{T_1}$	$\frac{R_1}{T_1}$	x	u	xu	σ	V
50	1.2833	.4113	.872	1.2468	.7	8.4928	5.945	.0172	5.9622
25		.3532	.9301	1.3604	.68363	16.2831	11.13	.0169	11.1469
10		.2832	1.0001	1.5042	.6652	38.3634	25.52	.0166	25.5366
5		.2348	1.0485	1.6084	.637	73.3135	46.636	.0165	46.6525
2		.1749	1.1084	1.7431	.63588	173.4836	110.31	.0164	110.3264

Table. 3.

Pressure 50# Quality .6

$\varphi = .4113 + (.6 \times 1.2468) = 1.1583$

P	φ	Θ	$\frac{xR_1}{T_1}$	$\frac{R_1}{T_1}$	x	u	xu	σ	V
50	1.1583	.4113	.747	1.2468	.6	8.4928	5.0957	.0172	5.1129
25		.3532	.8051	1.3604	.5918	16.2831	9.636	.0169	9.6529
10		.2832	.8751	1.5042	.5818	38.3634	22.32	.0166	22.3366
5		.2348	.9235	1.6084	.5705	73.3135	42.038	.0165	42.0545
2		.1749	.9834	1.7431	.56416	173.4836	97.873	.0164	97.8894

Pressure 100# Quality 1.

$\varphi = 1.602$

P	φ	Θ	$\frac{xR_1}{T_1}$	$\frac{R_1}{T_1}$	x	u	xu	σ	V
100	1.602	.4743	1.1277	1.1277	1.	4.4113	4.4113	.0177	4.429
75		.4474	1.1546	1.1778	.9801	5.7925	5.6774	.0175	5.6949
50		.4113	1.1907	1.2468	.955	8.4928	8.1106	.0172	8.1279
25		.3532	1.2488	1.3604	.91795	16.2831	14.946	.0169	14.9629
5		.2348	1.3672	1.6084	.85	73.3135	62.233	.0165	62.2495

Table. 4.

Pressure 100# — Quality 0.9

$\varphi = .4743 + (.9 \times 1.1277) = 1.4892$

P	φ	Θ	$\frac{xR_1}{T_1}$	$\frac{R_1}{T_1}$	x	u	xu	σ	V
100	1.4892	.4743	1.0149	1.1277	.9	4.4113	3.9702	.0177	3.9879
75		.4473	1.0419	1.1778	.8846	5.7925	5.1244	.0175	5.1419
50		.4113	1.0779	1.2468	.86453	8.4928	7.342	.0172	7.3592
25		.3532	1.1360	1.3604	.83503	16.2831	13.607	.0169	13.6239
5		.2348	1.2544	1.6084	.7799	73.3135	57.1	.0165	57.1165

Pressure 100# — Quality 0.8

$\varphi = .4743 + (.8 \times 1.1277) = 1.3765$

P	φ	Θ	$\frac{xR_1}{T_1}$	$\frac{R_1}{T_1}$	x	u	xu	σ	V
100	1.3765	.4743	.9022	1.1277	.8	4.4113	3.529	.0177	3.5467
75		.4473	.9292	1.1778	.78892	5.7925	4.57	.0175	4.5875
50		.4113	.9652	1.2468	.77412	8.4928	6.5746	.0172	6.5918
25		.3532	1.0233	1.3604	.7522	16.2831	12.25	.0169	12.2669
5		.2348	1.1417	1.6084	.7115	73.3135	52.09	.0165	52.1065

Table. 5.

Pressure 100# — Quality .7

$\varphi = .4743 + (.7 \times 1.1277) = 1.2637$

P	φ	Θ	$\frac{xR_1}{T_1}$	$\frac{R_1}{T_1}$	x	u	xu	σ	V
100	1.2637	.4743	.7894	1.1277	.7	4.4113	3.0879	.0177	3.1056
75		.4474	.8163	1.1778	.69307	5.7925	4.0149	.0175	4.0324
50		.4113	.8524	1.2468	.68364	8.4928	5.806	.0172	5.8232
25		.3532	.9105	1.3604	.6693	16.2831	10.9	.0169	10.9169
5		.2348	1.0289	1.6084	.6397	73.3135	46.835	.0165	46.8515

Pressure 100# — Quality .6

$\varphi = .4743 + (.6 \times 1.1277) = 1.2637$

P	φ	Θ	$\frac{xR_1}{T_1}$	$\frac{R_1}{T_1}$	x	u	xu	σ	V
100	1.1509	.4743	.6766	1.1277	.6	4.4113	2.6468	.0177	2.6645
75		.4474	.7035	1.1778	.5973	5.7925	3.46	.0175	3.4775
50		.4113	.7396	1.2468	.5932	8.4928	5.038	.0172	5.0552
25		.3532	.7977	1.3604	.58638	16.2831	9.5478	.0169	9.5647
5		.2348	.9161	1.6084	.5696	73.3135	41.7	.0165	41.7165

Table 6.

Pressure 150# — Quality 1

$\varphi = 1.5692$

P	φ	Θ	$\frac{xR_1}{T_1}$	$\frac{R_1}{T_1}$	x	u	xu	σ	V
150	1.5692	.5142	1.055	1.055	1.	2.9939	2.9939	.0181	3.012
100		.4743	1.0949	1.1277	.9709	4.4113	4.2828	.0177	4.3005
50		.4113	1.1579	1.2468	.9287	8.4928	7.887	.0172	7.9042
25		.3532	1.216	1.3604	.89382	16.2831	14.555	.0169	14.5719
5		.2348	1.3344	1.6084	.82963	73.3135	60.74	.0165	60.7565

Pressure 150# — Quality 0.9

$\varphi = .5142 + (.9 \times 1.055) = 1.4637$

P	φ	Θ	$\frac{xR_1}{T_1}$	$\frac{R_1}{T_1}$	x	u	xu	σ	V
150	1.4637	.5142	.9495	1.055	.9	2.9939	2.6945	.0181	2.7126
100		.4743	.9894	1.1277	.8773	4.4113	3.87	.0177	3.8877
50		.4113	1.0524	1.2468	.84408	8.4928	7.1685	.0172	7.1857
25		.3532	1.1105	1.3604	.8163	16.2831	13.27	.0169	13.3069
5		.2348	1.2289	1.6084	.76402	73.3135	55.94	.0165	55.9565

Table. 7.

Pressure 150# Quality 0.8

$\varphi = .5142 + (.8 \times 1.055) = 1.3582$

P	φ	θ	$\frac{xR_1}{T_1}$	$\frac{R_1}{T_1}$	X	u	xu	σ	V
150	1.3582	.5142	.844	1.005	.8	2.9939	2.3951	.0181	2.4132
100		.4743	.8839	1.1277	.78378	4.4113	3.4575	.0177	3.4752
50		.4113	.9469	1.2468	.75945	8.4928	6.45	.0172	6.4672
25		.3532	1.005	1.3604	.73875	16.2831	12.08	.0169	12.0969
5		.2348	1.1234	1.6084	.71473	73.3135	52.33	.0165	52.3465

Pressure 150# Quality 0.7

$\varphi = .5142 + (.7 \times 1.055) = 1.2527$

P	φ	θ	$\frac{xR_1}{T_1}$	$\frac{R_1}{T_1}$	X	u	xu	σ	V
150	1.2527	.5142	.7385	1.005	.7	2.9939	2.0857	.0181	2.1038
100		.4743	.7784	1.1277	.69023	4.4113	3.045	.0177	3.0627
50		.4113	.8414	1.2468	.67483	8.4928	5.7322	.0172	5.7494
25		.3532	.8995	1.3604	.6612	16.2831	10.765	.0169	10.7819
5		.2348	1.0179	1.6084	.63294	73.3135	46.334	.0165	46.3505

Table. 8.

Pressure 150# Quality 0.6

$\varphi = .5142 + .6 \times 1.055 = 1.1472$

P	φ	Θ	$\frac{XR_1}{T_1}$	$\frac{R_1}{T_1}$	X	U	XU	σ	V
150	1.1472	.5142	.633	1.055	.6	2.9939	1.7963	.0181	1.8144
100		.4743	.6729	1.1277	.59668	4.4113	2.632	.0177	2.6497
50		.4113	.7359	1.2468	.59023	8.4928	5.0127	.0172	5.0299
25		.3532	.794	1.3604	.58364	16.2831	9.5033	.0169	9.5202
5		.2348	.9124	1.6084	.56726	73.3135	41.53	.0165	41.5465

Pressure 200# Quality 1.

$\varphi = 1.5456$

P	φ	Θ	$\frac{XR_1}{T_1}$	$\frac{R_1}{T_1}$	X	U	XU	σ	V
200	1.5456	.5437	1.0019	1.0019	1.	2.27155	2.27155	.01845	2.29
100		.4743	1.0713	1.1277	.9502	4.4113	4.1828	.0177	4.2005
50		.4113	1.1343	1.2468	.909	8.4928	7.72	.0172	7.7372
25		.3532	1.1924	1.3604	.8765	16.2831	14.27	.0169	14.2869
10		.2832	1.2624	1.5042	.83923	38.3634	32.195	.0166	32.2116

Table. 9.

Pressure 200# Quality 0.9

$\varphi = .5437 + (.9 \times 1.0019) = 1.4454$

P	φ	θ	$\frac{xR_1}{T_1}$	$\frac{R_1}{T_1}$	x	u	xu	σ	V
200	1.4454	.5437	.9017	1.0019	.9	2.27155	2.0444	.01845	2.06285
100		.4743	.9711	1.1277	.8611	4.4113	3.799	.0177	3.8167
50		.4113	1.0341	1.2468	.8294	8.4928	7.044	.0172	7.0612
25		.3532	1.0922	1.3604	.8028	16.2831	13.72	.0169	13.7369
10		.2832	1.1622	1.5042	.77263	38.3634	29.64	.0166	29.6566

Pressure 200# Quality 0.8

$\varphi = .5437 + (.8 \times 1.0019) = 1.3452$

P	φ	θ	$\frac{xR_1}{T_1}$	$\frac{R_1}{T_1}$	x	u	xu	σ	V
200	1.3452	.5437	.8015	1.0019	.8	2.27155	1.81724	.01845	1.83569
100		.4743	.8709	1.1277	.77225	4.4113	3.407	.0177	3.5247
50		.4113	.9339	1.2468	.74847	8.4928	6.3566	.0172	6.3738
25		.3532	.992	1.3604	.72919	16.2831	11.872	.0169	11.8889
10		.2832	1.062	1.5042	.70537	38.3634	27.056	.0166	27.0726

Table 10.

Pressure 200# Quality 0.7

$\varphi = .5437 + (.7 \times 1.0019) = 1.245$

P	φ	θ	$\frac{XR_1}{T_1}$	$\frac{R_1}{T_1}$	X	U	XU	σ	V
200	1.245	.5437	.70133	1.0019	.7	2.27155	1.59009	.01845	1.60954
100		.4743	.7707	1.1277	.6834	4.4113	3.015	.0177	3.0327
50		.4113	.8337	1.2468	.66866	8.4928	5.679	.0172	5.6962
25		.3532	.8918	1.3604	.65555	16.2831	10.675	.0169	10.6919
10		.2832	.9618	1.5042	.6394	38.3634	24.23	.0166	24.2466

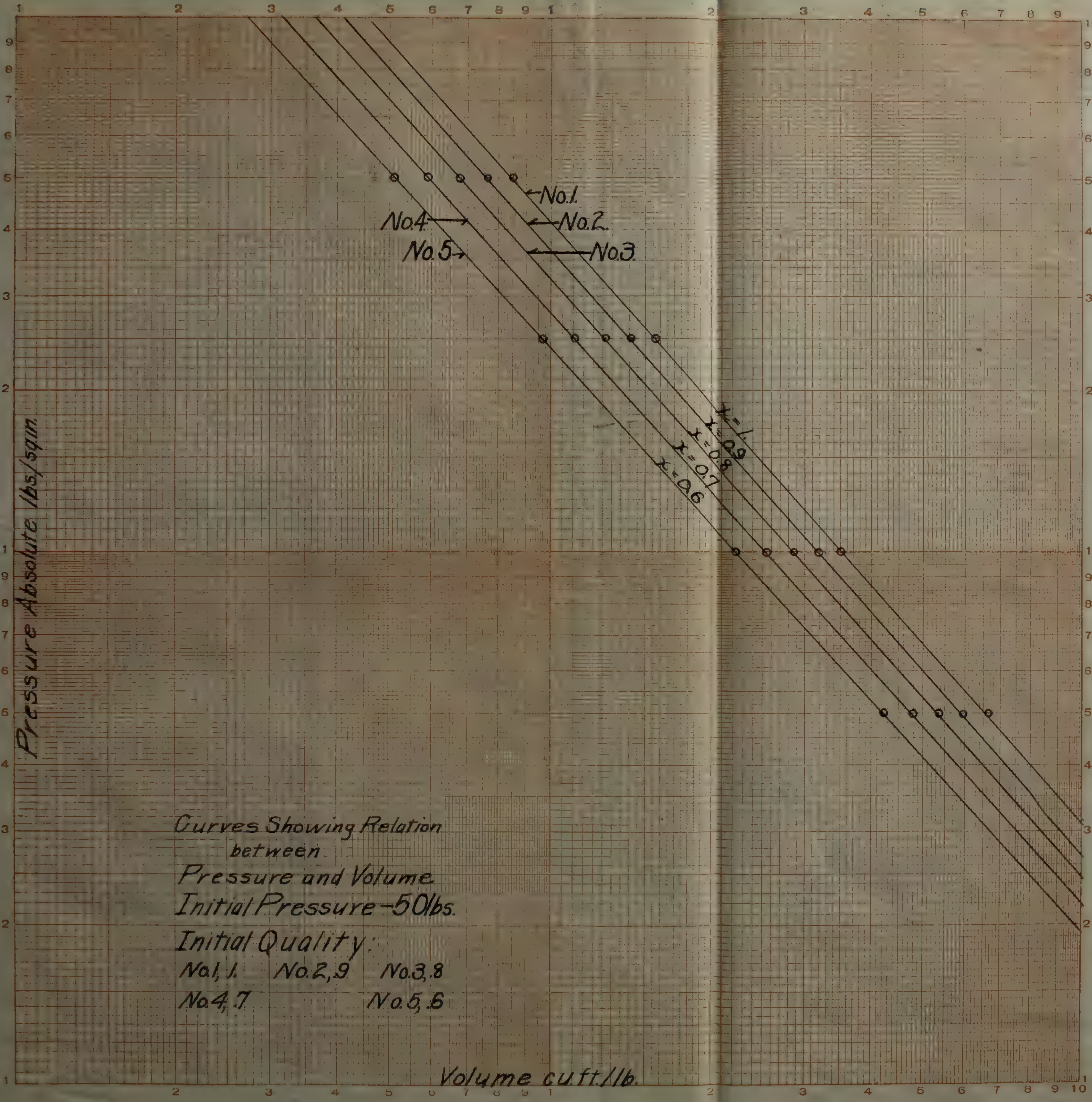
Pressure 200# Quality 0.6

$\varphi = .5437 + (.6 \times 1.0019) = 1.1448$

P	φ	θ	$\frac{XR_1}{T_1}$	$\frac{R_1}{T_1}$	X	U	XU	σ	V
200	1.1448	.5437	.60114	1.0019	.6	2.27155	1.36293	.01845	1.38138
100		.4743	.6705	1.1277	.59455	4.4113	2.6222	.0177	2.6399
50		.4113	.7335	1.2468	.5883	8.4928	4.9964	.0172	5.0136
25		.3532	.7916	1.3604	.5819	16.2831	9.4748	.0169	9.4917
10		.2832	.8616	1.5042	.572	38.3634	21.97	.0166	21.9866

Plate. I.


Pressure Absolute lbs/sqin.
Curve
Pres
Initi
Initia
No.1, 1.
No.4,



No.1.
No.2.
No.3.
No.4
No.5
x=1.
x=0.9
x=0.8
x=0.7
x=0.6
Pressure Absolute lbs/sq.in.
Volume cu.ft./lb.
Curves Showing Relation
between
Pressure and Volume
Initial Pressure -50lbs.
Initial Quality:
No.1, 1. No.2, .9 No.3, .8
No.4, .7 No.5, .6

Plate. 2.

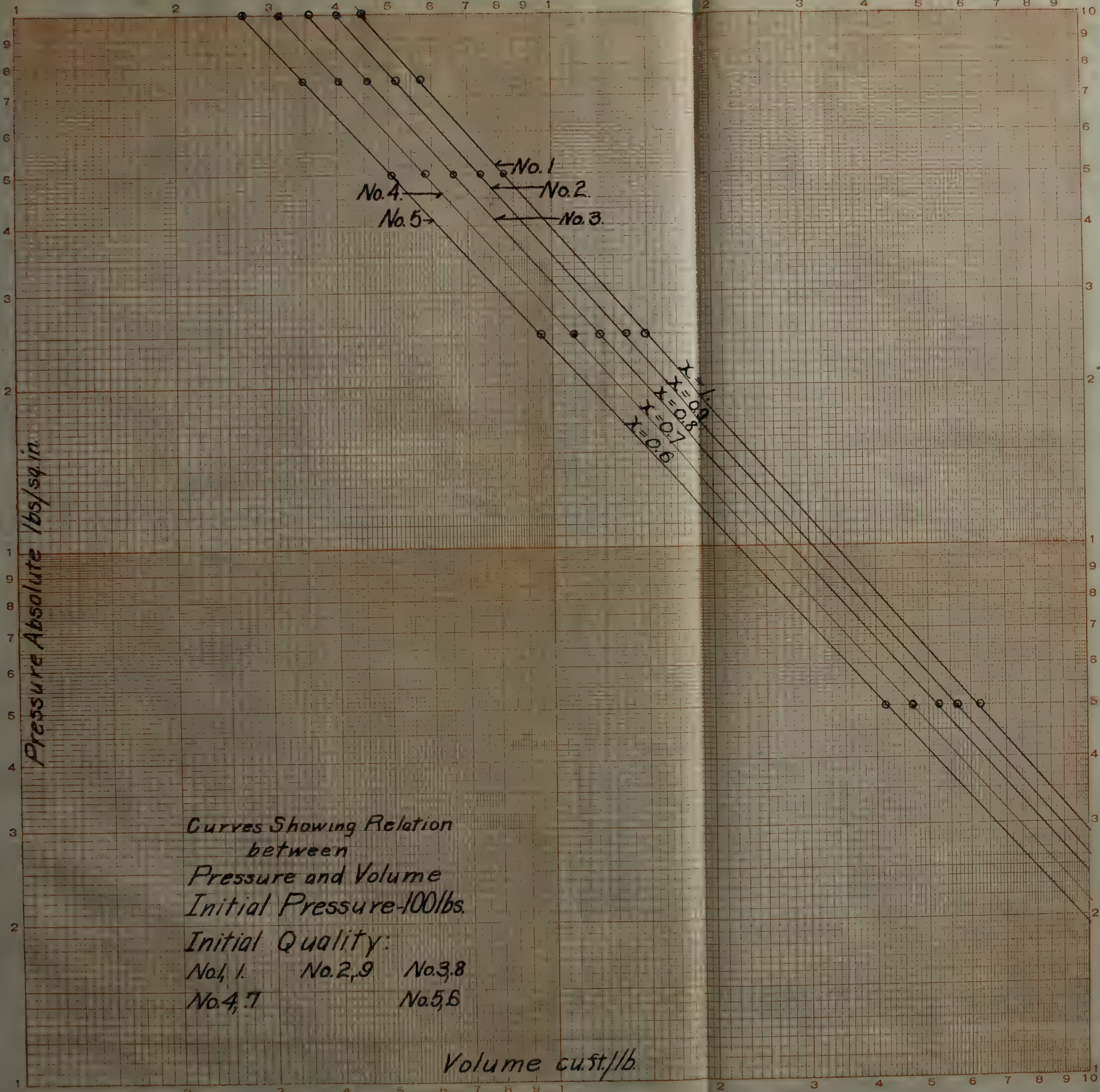
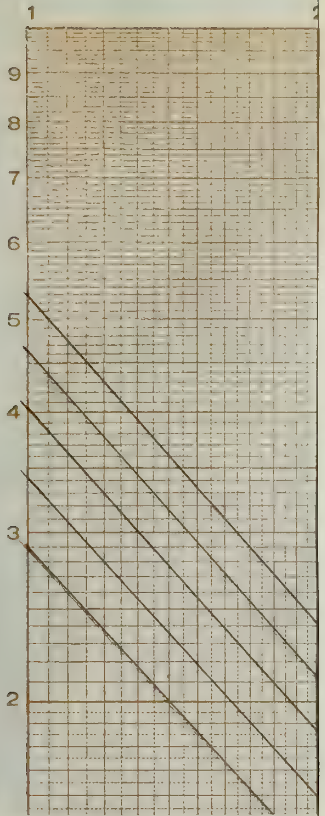
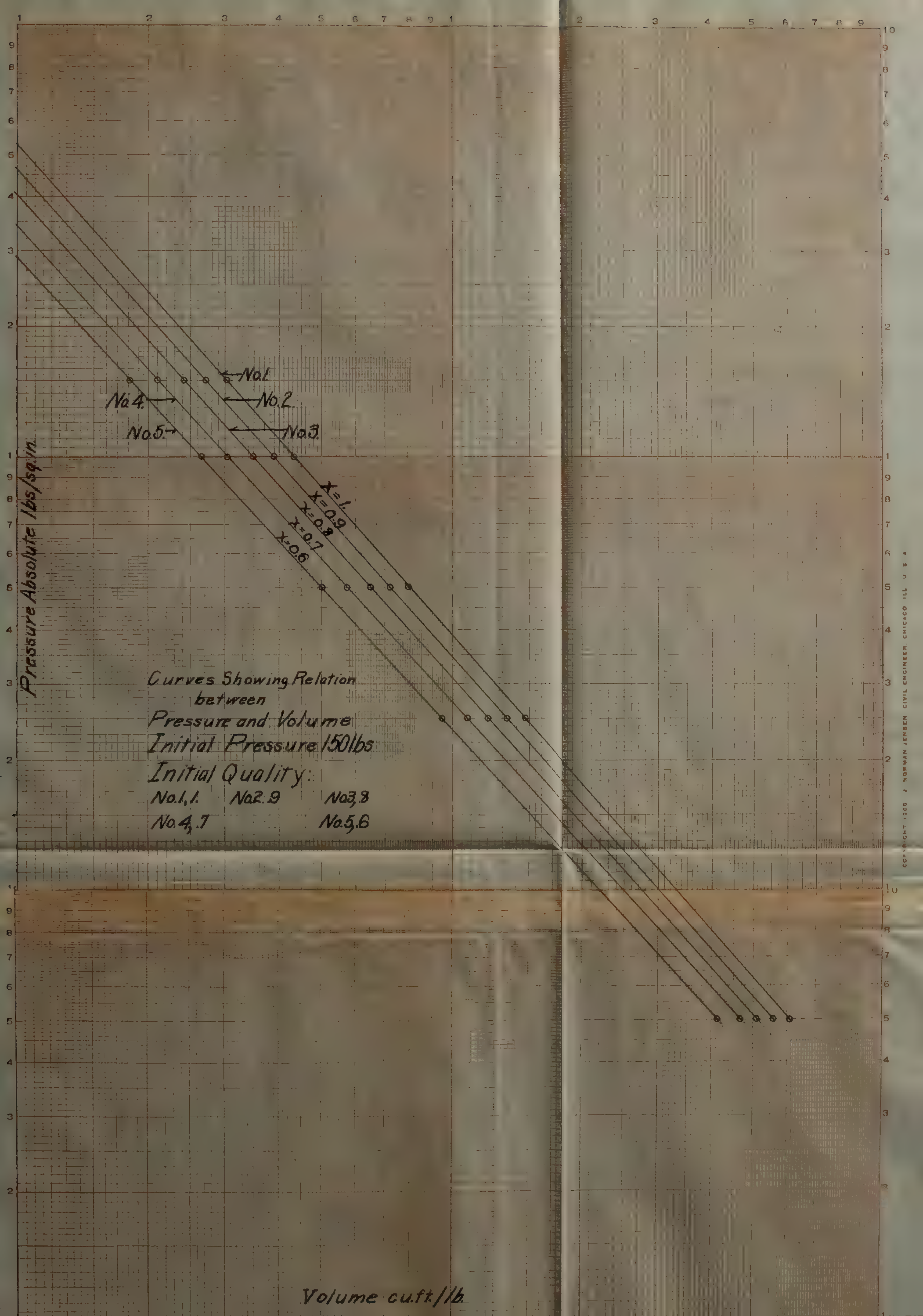

Curves Showing Relation
between
Pressure and Volume
Initial Pressure-100 lbs.
Initial Quality:
No.1, 1. No.2, .9 No.3, .8
No.4, .7 No.5, .6
No. 1
No. 2
No. 3
No. 4
No. 5
X = 1.
X = 0.9
X = 0.8
X = 0.7
X = 0.6
Pressure Absolute lbs/sq.in.
Volume cu.ft./lb.

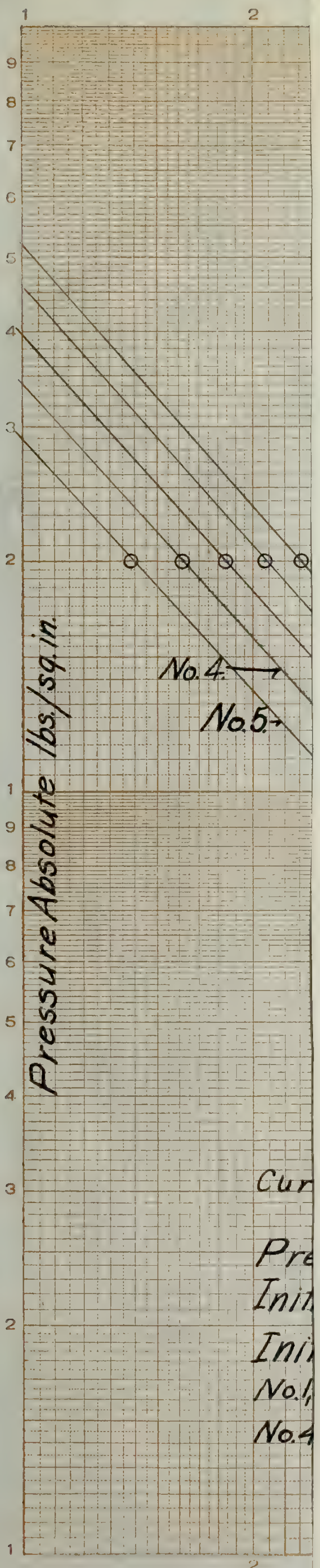
Plate. 3.

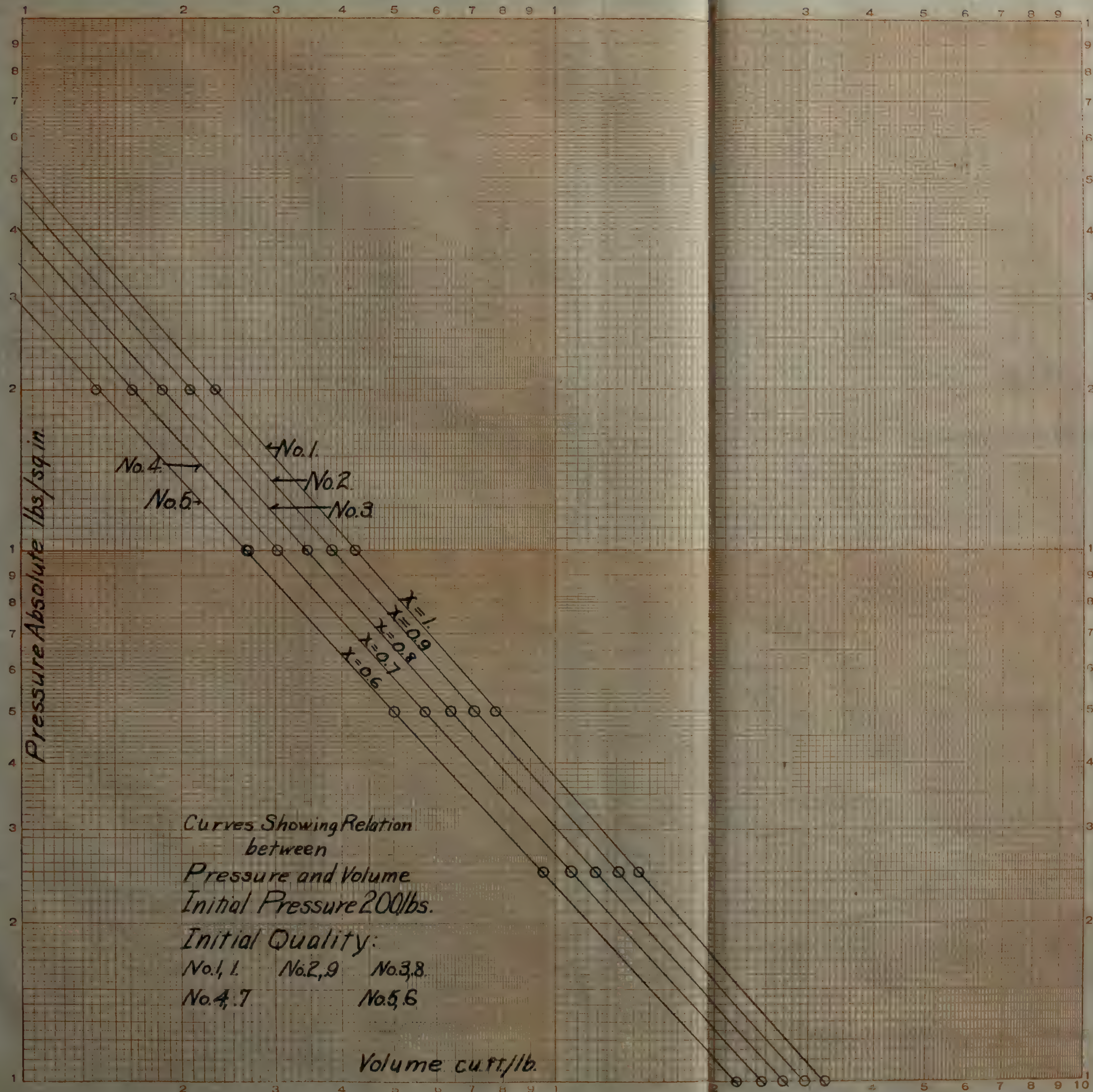


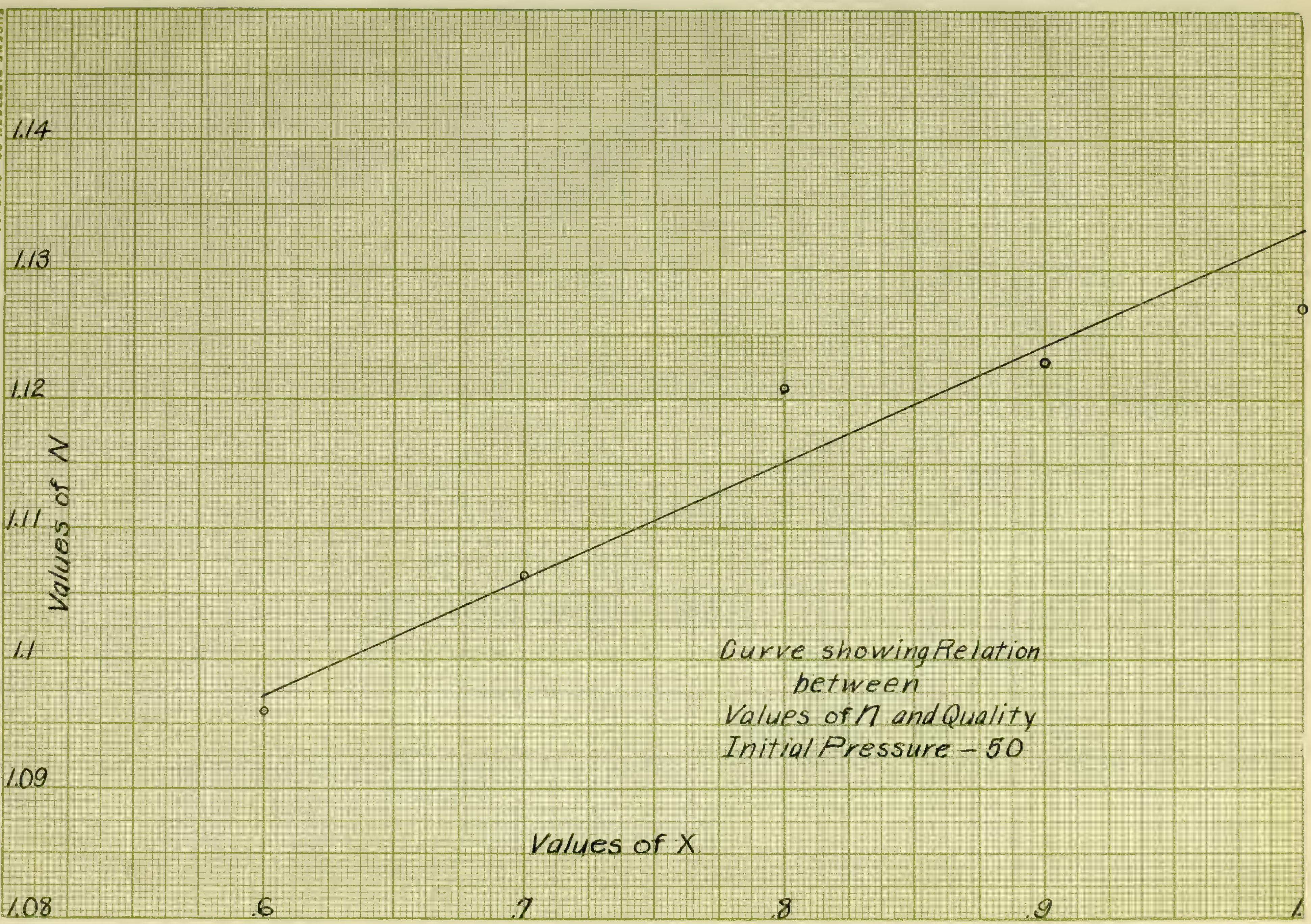


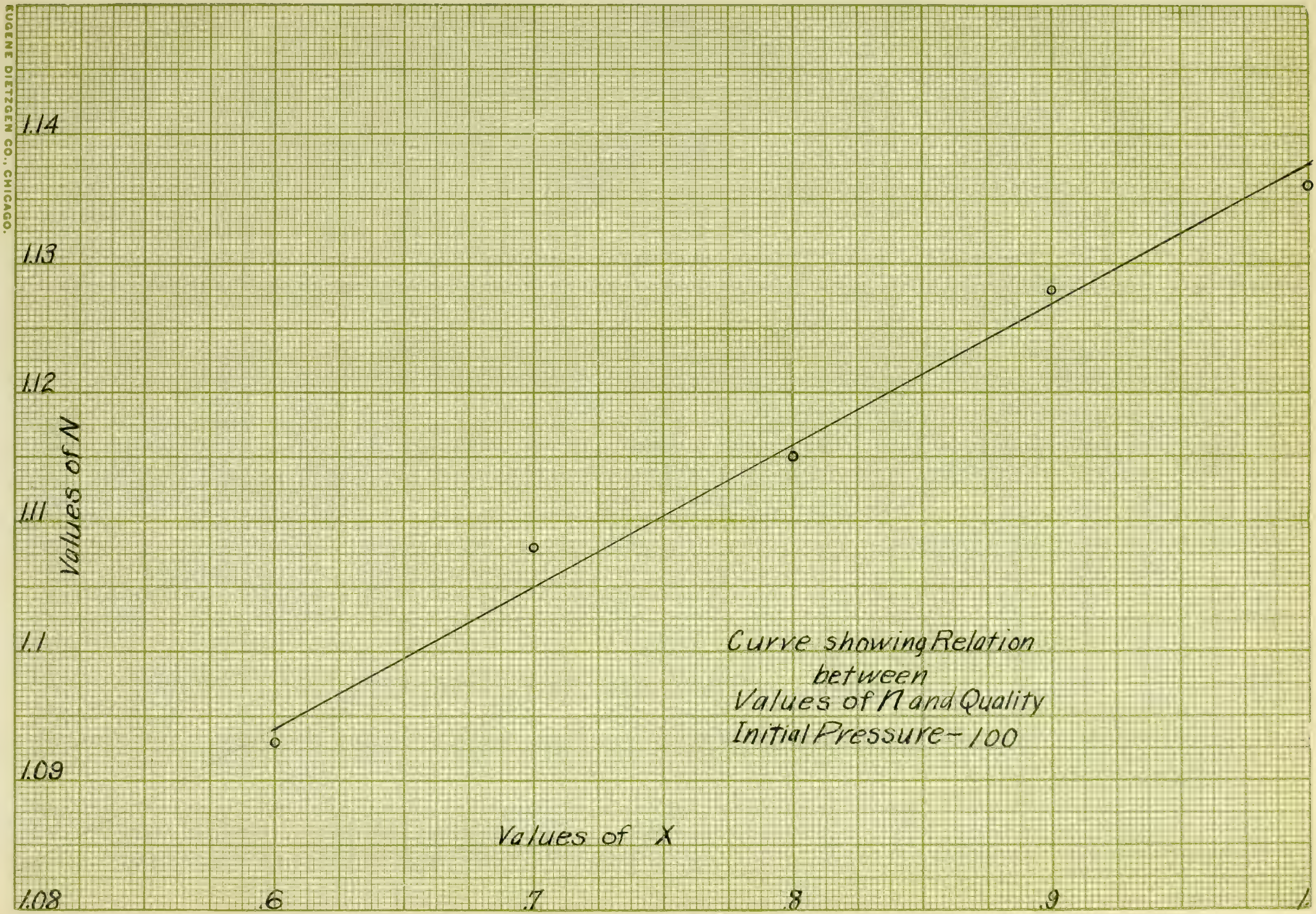
Pressure Absolute lbs/sq.in.
Volume cu.ft./lb.
No.1
No.2
No.3
No.4
No.5
X=1.
X=0.9
X=0.8
X=0.7
X=0.6
Curves Showing Relation
between
Pressure and Volume
Initial Pressure 150lbs
Initial Quality:
No.1,1. No.2 .9 No.3 .8
No.4 .7 No.5 .6

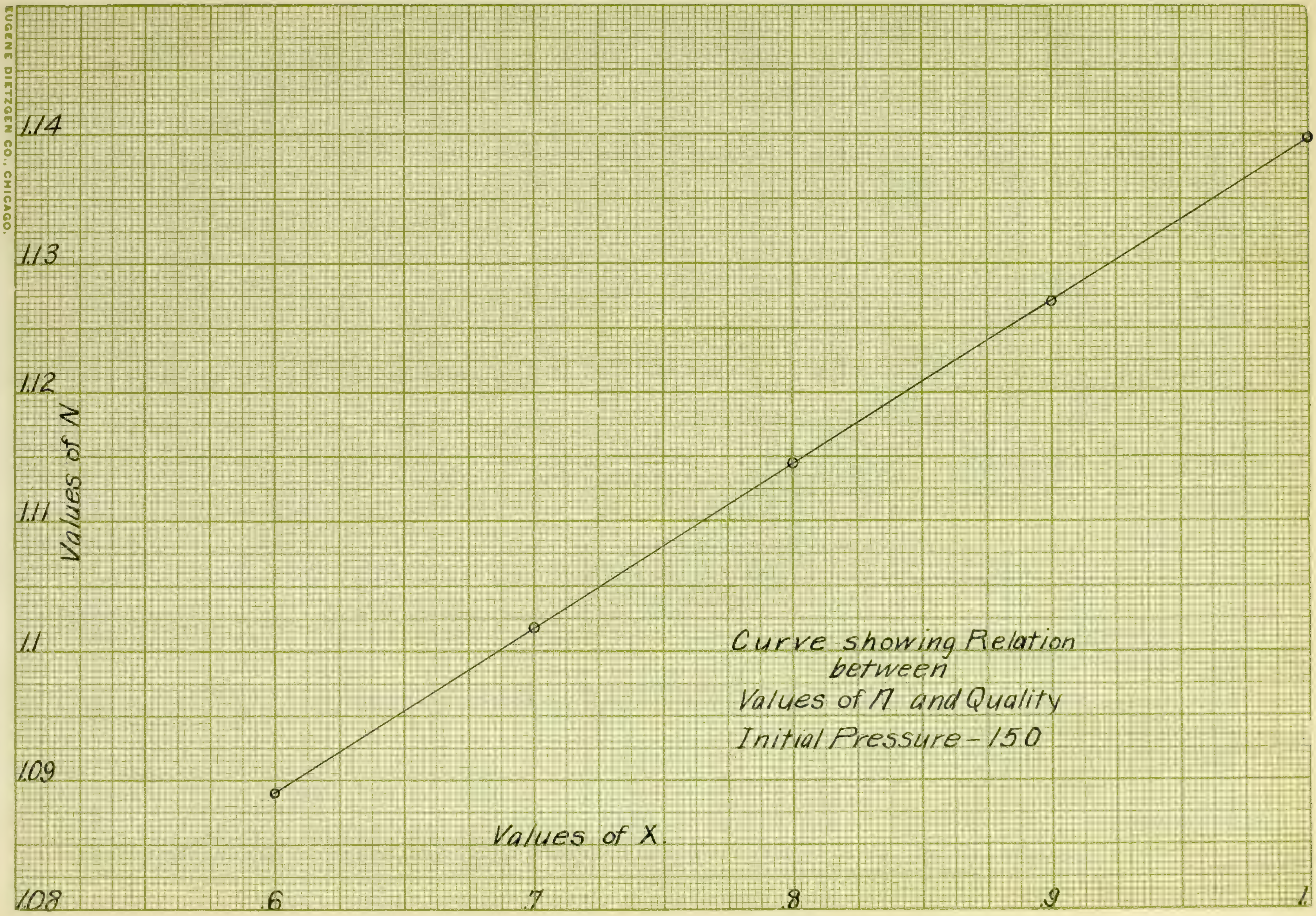
Plate.4.

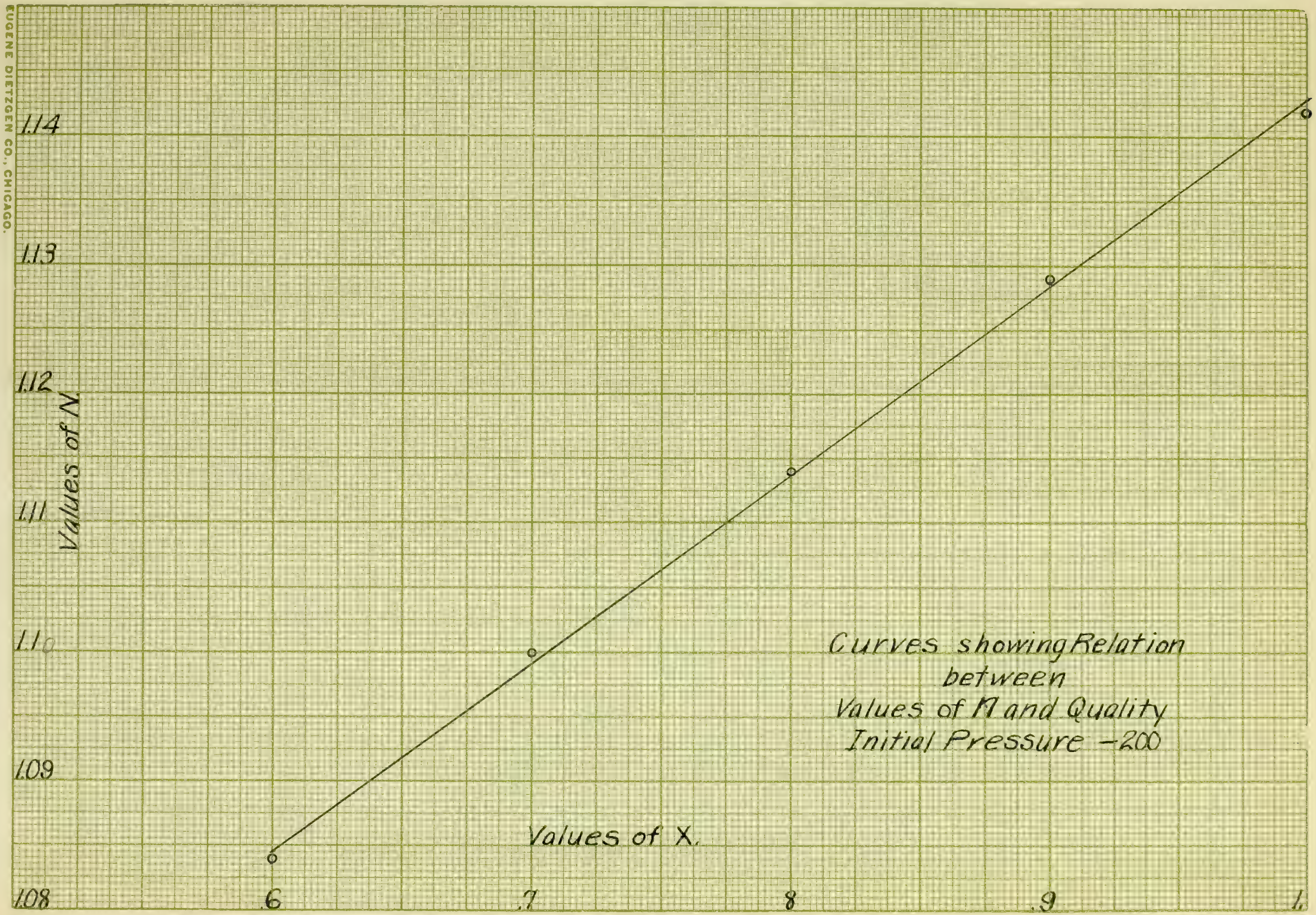


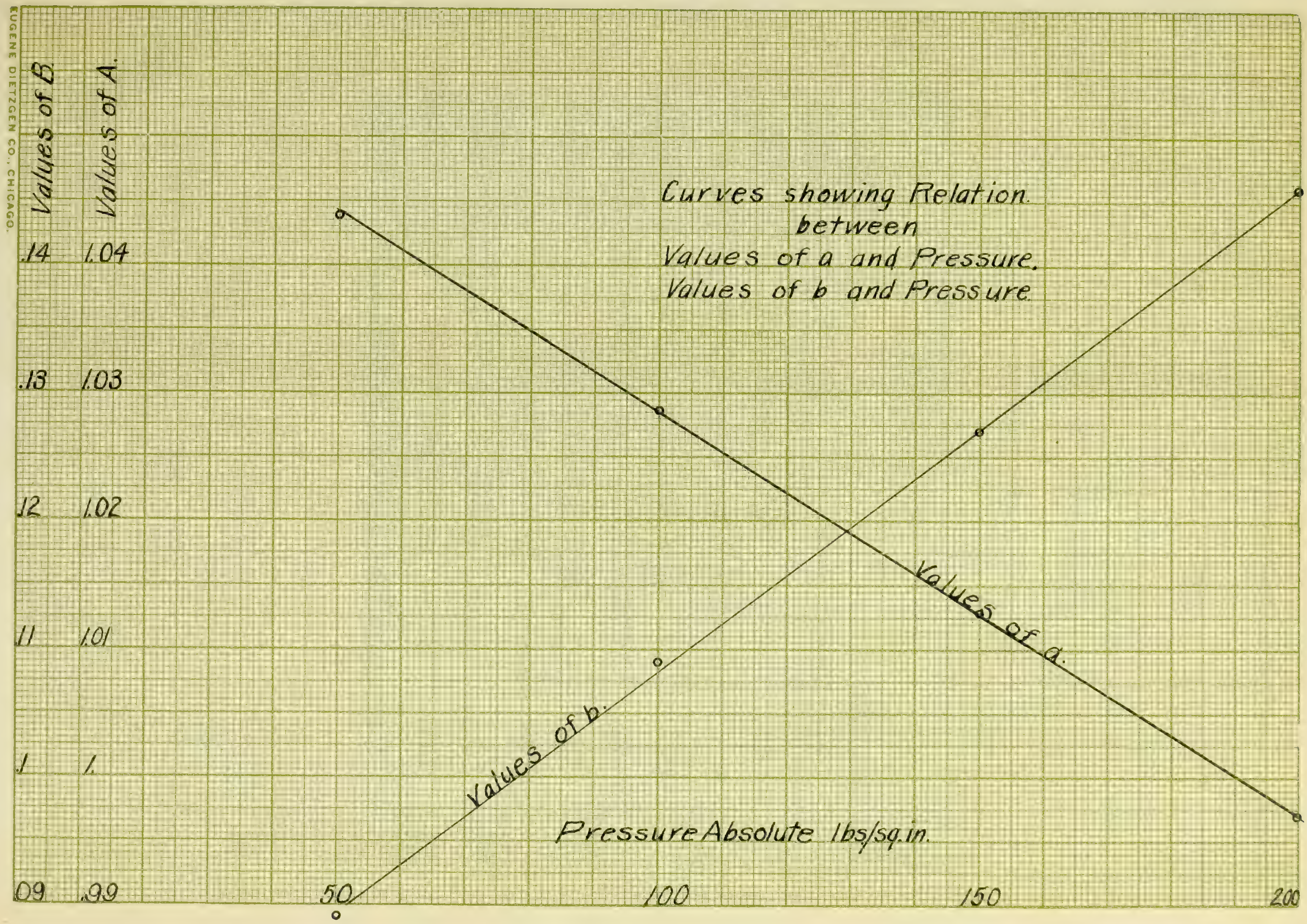

Pressure Absolute lbs./sq.in.
Volume cu.ft./lb.
No.1.
No.2.
No.3.
No.4.
No.5.
X=1.
X=0.9
X=0.8
X=0.7
X=0.6
Curves Showing Relation
between
Pressure and Volume
Initial Pressure 200 lbs.
Initial Quality:
No.1, 1. No.2, .9 No.3, .8
No.4, .7 No.5, .6


Curve showing Relation
between
Values of N and Quality
Initial Pressure – 50
Values of N
Values of X
1.14
1.13
1.12
1.11
1.1
1.09
1.08
.6
.7
.8
.9
1.


Curve showing Relation
between
Values of N and Quality
Initial Pressure - 100
Values of N
Values of X
1.14
1.13
1.12
1.11
1.1
1.09
1.08
.6
.7
.8
.9
1.


Curve showing Relation
between
Values of N and Quality
Initial Pressure - 150
Values of N
Values of X.
1.14
1.13
1.12
1.11
1.1
1.09
1.08
.6
.7
.8
.9
1.


Curves showing Relation
between
Values of N and Quality
Initial Pressure -200
Values of N.
Values of X.
1.14
1.13
1.12
1.11
1.10
1.09
1.08
.6
.7
.8
.9
1.


Curves showing Relation
between
Values of a and Pressure.
Values of b and Pressure.
Values of B
Values of A.
.14
1.04
.13
1.03
.12
1.02
.11
1.01
.1
1.
.09
.99
50
100
150
200
Values of a.
Values of b.
Pressure Absolute lbs/sq.in.

Range Q	Range P_1-P_2	P_1	V.	E_1	E_2	$(E_1-E_2)777.5$	Error %
1.	50-2	50	8.51	095.	907.98	145,400.	.213
1.	100-5	100	4.429	104.6	922.66	141,460.	.205
1.	100-25	100	4.429	104.6	1013.18	71,780.	.209
1.	100-50	100	4.429	104.6	1056.915	37,075.	.014
1.	150-5	150	3.012	110.1	903.66	160,507.	1.078
1.	150-100	150	3.012	110.1	1081.09	22,555.	.107
1.	200-100	200	2.29	113.7	1063.4	39,107.	.156
0.6	100-5	100	2.665	81.93	661.17	91,755.	.962
0.6	100-50	100	2.665	81.93	751.2	23,892.	1.13

Problems in Change of Energy.

Range							Correct	Error								Error
Q	$P_1 - P_2$	P_1	V_1	$P_1 V_1$	P_2	V_2	V_2	%	$P_2 V_2$	$P_1V_1 - P_2V_2$	$n-1$	$\left(\frac{P_1V_1 - P_2V_2}{n-1}\right)144$	E_1	E_2	$(E_1 - E_2)777.5$	%
1.	50-2	50	8.51	425.5	2	145.6	147.6	1.35	291.2	134.3	.1336	145,090.	1095.	907.98	145,400.	.213
1.	100-5	100	4.429	442.9	5	61.775	62.25	.765	308.88	134.02	.1367	141,170.	1104.6	922.66	141,460.	.205
1.	100-25	100	4.429	442.9	25	14.996	14.963	.221	374.9	68.	.1367	71,630.	1104.6	1013.18	71,780.	.209
1.	100-50	100	4.429	442.9	50	8.154	8.128	.318	407.7	35.2	.1367	37,080.	1104.6	1056.915	37,075.	.014
1.	150-5	150	3.012	451.2	5	59.53	60.76	2.024	297.65	154.15	.1398	158,780.	1110.1	903.66	160,507.	1.078
1.	150-100	150	3.012	451.8	100	4.2988	4.3005	.038	429.88	21.92	.1398	22,579.	1110.1	1081.09	22,555.	.107
1.	200-100	200	2.29	458.	100	4.2023	4.2005	.043	420.23	37.77	.1428	39,046.	1113.7	1063.4	39,107.	.156
.06	100-5	100	2.665	266.5	5	41.28	41.717	1.055	206.4	60.1	.09342	92,638.	781.93	661.17	91,755.	.962
.06	100-50	100	2.665	266.5	50	5.0235	5.0552	.627	251.175	15.325	.09342	23,622.	781.93	751.2	23,892.	1.13